CALMScience Supplement 4: 93-100 (1995)

Analysis of rural ignition patterns on Canberra's urban/rural interface

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ABSTRACT

An approach to using records of man-made ignition patterns, as part of the overall system for rural fire hazard management in the ACT, is presented. The area being managed has been divided into blocks exhibiting a relatively uniform land-use pattern. A predictive model relates expected number of ignitions per square kilometre per annum to distance from suburbs and principal land-use.

The relationship between ignition rates, land-use types and distance from nearest suburbs shows that Canberra Nature Park, industrial lands, commercial sites and pine plantations all have relatively frequent ignitions (expressed as number of fires per square kilometre per annum) close to suburbs. Ignition rates in the Nature Park and commercial sites decline rapidly as distance from nearest suburbs increases. Rural lands have constant, low ignition rates.

Some implications of these patterns are discussed. An urban/rural interface transition zone can be defined using the model. The model allows improved liaison with planning authorities and land managers. It also offers a quantitative method for setting standards of fire response.

INTRODUCTION

The urban/rural interface of Canberra is a major problem for fire managers and land managers. The basic planning philosophy of Canberra as a 'bush capital', with abundant open space (Seddon 1977), has led to discrete town centres being developed, separated by hills and ridges that are left undeveloped. The growth of the city is by means of the building of largely contiguous new suburbs, each of which replaces traditional rural land-uses. There is thus a very convoluted and long interface[1]. A recent trend towards urban consolidation may do little to counter this. The interface is almost entirely classic [clearly demarcated transition], with some occluded interface [rural intruding into urban] and very little mixed interface [urban outliers in rural areas] (using the terms of Laughlin and Page 1987).

As part of an assessment of rural fire hazard in the ACT (McRae 1991), the following process was carried out:

- Define the problem to be addressed. Here rural fire hazard was defined as being:

Hazard: *A measure of how frequently fires occur, how quickly they spread and how close they are to life and property.*

This may be restated from an operational perspective as being a need to provide quick detection, quick response and quick suppression.

- Devise a process that allows a quantitative or semi-quantitative assessment of hazard. This was done through a flow chart that led from raw data through to modelled indices (Fig. 1).
- Devise ways of using the assessment to guide management and planning for land-use and fire. If the hazard were assessed as being high, then working backwards through the flow chart provides an indication of the most effective ways of mitigating the hazard - and also indicates which factors are not able to be managed (such as being prone to natural - i.e. lightning - ignitions, see Figure 2). Further, the modelling software indicates which of the component indices contributed most to the hazard value. These guides permit cost-effective hazard mitigation.

Achieving the relatively straight-forward process outlined above proved quite difficult in a number of respects. The prediction of areas prone to lightning ignition required a new procedure to be developed

[1] With a population of over 290 000 in 1993, Canberra had an interface estimated to be 1400 km in length.

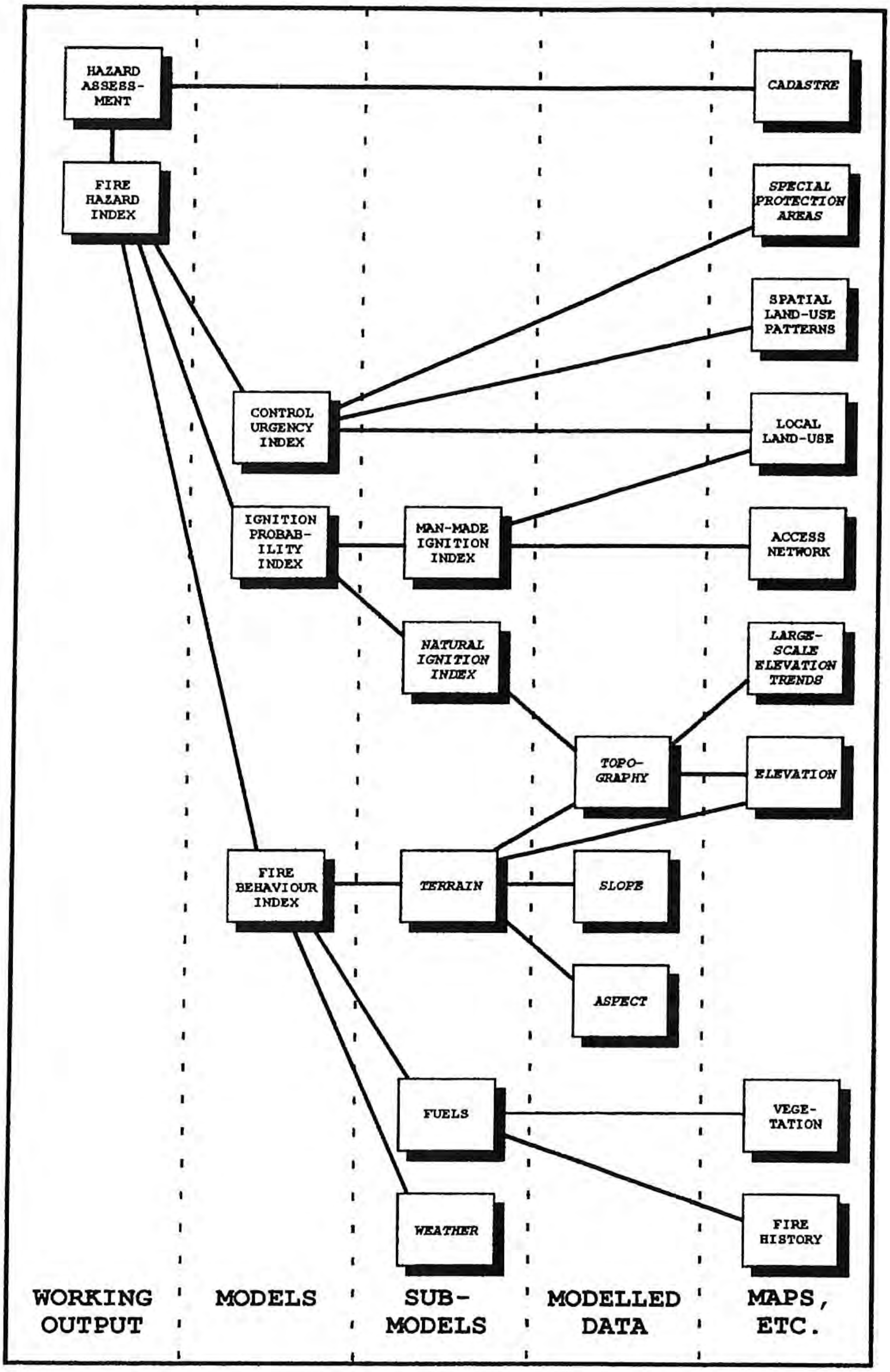

Figure 1. Flowchart for ACT rural fire hazard assessment. Those boxes labelled in italics show factors that cannot be managed to mitigate hazard levels.

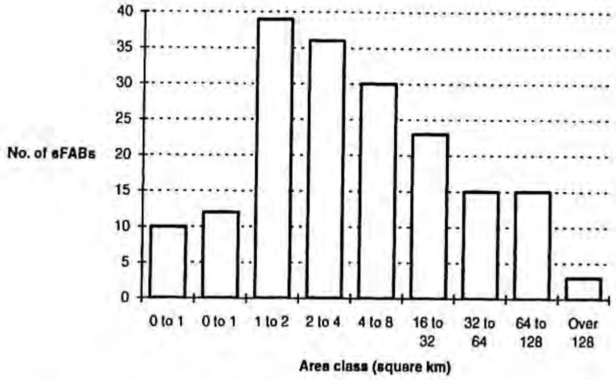

Figure 2. Area distributions for sub-Fire Accounting Blocks in the ACT.

(McRae 1992). There was little known about the spatial distribution of ignition patterns around Canberra's urban interface, or even their distribution among generic land-use types. The ACT Bush Fire Council's fire records archive proved an invaluable and almost complete source of information, allowing many of the problems to be solved.

The full-time emergency agencies in the ACT are now combined as the Emergency Management Group, with agency identities retained, but centralizing of all support roles. This group is revitalizing the Emergency Planning process, and has adopted an 'all-hazards' approach to finding the balance between:

- overall threats to the community;
- agencies' capabilities to respond to emergencies;
- the need for cost effectiveness.

METHODS

As part of the assessment of rural fire hazard in the ACT, and the on-going establishment of a quantitative foundation for the new Emergency Management Group, a number of steps have been taken towards a quantitative analysis of fire ignition patterns. This paper deals with one aspect of this work - the detailed relationships between ignition frequency and land-use and proximity to suburban development.

The ACT was divided into a series of blocks with relatively uniform land-use patterns, called Fire Accounting Blocks (**FABs**). Some of these were divided further, by progressing into a finer scale of resolution, into sub-**FABs** (**sFABs**). There were 182 of these. For each **sFAB**, the area in square kilometres was calculated, and the number of recorded fires over the last 11 years was noted from operational archives. The observed average number of fires per square kilometre per annum, the Man-made Ignition Index (**MII**$_{Obs}$), was calculated as the fire tally divided by the area divided by 11, the number of years of observation. Changes in land-use during the time interval were taken into account. The frequency distribution of **sFABs** in area classes is shown in Figure 2.

The principal land-use (**PLU**) for each **sFAB** was determined from maps, air photos and office records. A distance (**DIST**), in kilometres, from the centre of each **sFAB** to the nearest edge of suburban development was calculated.

A line of best fit was obtained which, for each **PLU**, could predict ignition frequency (**MII**$_{Prc}$) given **DIST**. The equation for the model is:

$$MII_{Prc} = e^{a*} \quad e^{(b* \ DIST)}$$

which was reduced to a linear form that allowed easier fitting of the constants:

$$\log_e(MII_{Prc}) = a + b* \quad DIST$$

The values of a and b were determined for each principal land-use. Unfortunately, low sample sizes prevented formal regression analysis, lines instead being fitted to the data by eye.

RESULTS

The values of the constants are shown in Table 1 and the curves generated by the model for each land-use are graphed in Figure 3. The general nature of the equation is that with increasing distance from suburbs the ignition frequency starts from an initial value and declines towards zero. The initial value varies widely, as does the rate of decline. In one case the rate of decline is zero, i.e. the value is constant.

In general, small sample sizes ruled out a quantitative assessment of the goodness of fit for the model. However, the general trends are clear enough for the model to be useful. Further work is required to improve the statistical rigour of the model.

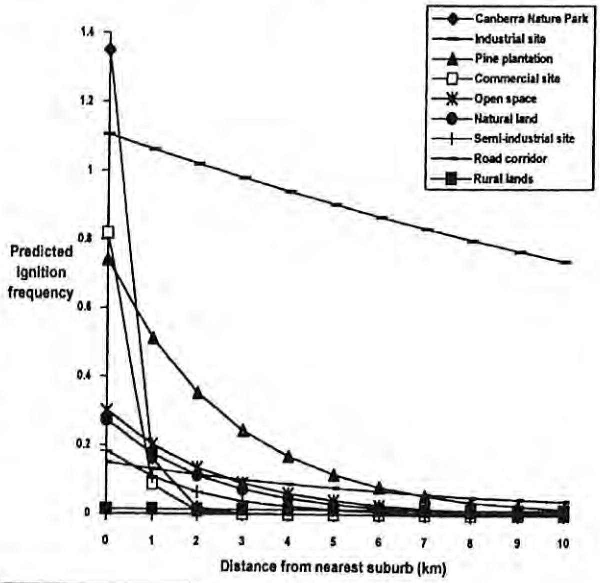

Figure 3. The relationship between predicted ignition frequency and distance from nearest suburb (ranging up to 10 km) for each principal land-use.

TABLE 1

The areas of each principal land-use type, together with the values of the two constants used in the predictive model for ignition frequency. Also shown for the land-uses are categories (zero, low, moderate and high) describing the relative initial value of ignition frequency and its relative rate of decline with distance from nearest suburb.

PRINCIPAL LAND-USE	AREA (km^2)	VALUE FOR CONSTANT A	VALUE FOR CONSTANT B	INITIAL VALUE OF IGNITION FREQUENCY	RATE OF DECLINE OF IGNITION FREQUENCY
Canberra Nature Park[a]	56	0.3	-2.1	High	High
Industrial site	16	0.1	-0.04	High	Low
Pine plantation	235	-0.3	-0.4	Moderate	Moderate
Commercial site	15	-0.2	-2.2	Moderate	High
Open space	30	-1.2	-0.4	Moderate	Moderate
Natural land	1090	-1.3	-0.4	Moderate	Moderate
Semi-industrial site	10	-1.7	-0.5	Low	Moderate
Road corridor	93	-1.9	-0.1	Low	Low
Rural lands	526	-4.3	0	Low	Zero
Urban	150	n.a.	n.a.	n.a.	n.a.

[a]C.N.P. is a series of discrete natural or semi-natural land parcels in and around the city, managed for recreation and conservation.

APPLICATIONS - RESPONDING TO PATTERNS IN IGNITION FREQUENCIES

The predicted ignition frequency model assumes that all of the spatial pattern in ignition frequencies can be related to distance from closest suburb and principal land-use. To interpret this, the suburbs may be viewed as a source of ignition in the form of people going into nearby open-space and related areas for various purposes, but in the process causing fires, either maliciously, carelessly or accidentally. The destination can be either 'whatever is on the other side of the fence', or some specific attraction, such as a favoured picnic spot or a site favoured because arson may be carried out with little risk of detection. However, the magnitude of all of these effects declines with distance from suburbs.

Among the issues arising from this that are now being addressed in the ACT are:

(1) Definition of an interface transition zone.
(2) Liaison with planning authorities.
(3) Liaison with land managers.
(4) Standards of fire response.
(5) Decision support for dispatch.

Definition of an Interface Transition Zone

The predicted ignition frequency patterns can be used to define an urban/rural interface transition zone. Rather than addressing the interface itself, this approach considers the transition zone on the rural side of it where rural fires are most frequent.

The zone can be defined as including all points where predicted ignition frequency exceeds a specified value. (Lands closer in to the suburbs with different principal land-use may be outside the zone.) Two approaches to the cut-off value examined are:

- Predicted ignition frequency is 50 per cent of what it would have been if that land were adjacent to suburbia.
- A constant value for predicted ignition frequency (such as 1.0, 0.5 or 0.25 fires per square kilometre per annum).

Table 2 shows the results of these.

From the perspective of fire management in the ACT, no formal definition has yet been adopted, but that based on a predicted ignition frequency of 0.25 fires per square kilometre per annum appears the most valuable as a starting point as it quantifies existing working arrangements. The zone resulting from this is identified in the map in Figure 4.

TABLE 2

Definitions of the interface transition zone, based on distance from suburbs to achieve specified ignition frequencies. All distances are given in kilometres.

PRINCIPAL LAND-USE	DISTANCE TO 50 PER CENT OF MAXIMUM FREQUENCY	DISTANCE TO 1.0 FIRES PER km^2 PER ANNUM	DISTANCE TO 0.5 FIRES PER km^2 PER ANNUM	DISTANCE TO 0.25 FIRES PER km^2 PER ANNUM
Canberra Nature Park	0.33	0.14	0.47	0.80
Industrial site	17.31	2.5	19.83	37.16
Pine plantation	1.88		1.06	2.94
Commercial site	0.90		0.22	0.53
Open space	1.74			0.47
Natural land	1.58			0.20
Semi-industrial site	1.32			
Road corridor	5.34			
Rural lands	n.a.			
Urban	n.a.			

Figure 4. Map of the ACT urban/rural interface transition zone (shaded black). The outlined areas are suburban development.

Land-use Planning Guidance

The model can be used to guide cost-effective land-use planning. Planning authorities are constantly attempting to balance a broad-spectrum of competing demands in urban or rural environments. One of these, protection from wildfire, has rarely been satisfactorily quantified, and has thus often been given a lower priority than factors such as visual and recreational amenity or traffic flow. Changes in public perceptions and the threat of massive economic impact following large wildfires are forcing a change in both the effort expended in addressing the threat and in prioritizing protection measures.

Obvious strategies suggested by this include:

- Conducting an assessment of the overall impact on the local fire problem arising from a development proposal, allowing cost effective fire protection and forecasting of impacts on the workloads of fire agencies.
- Liaising with planners to ensure that lands adjoining new suburbs are not those with the highest predicted ignition frequency. For example, general open space is better from this perspective than a pine forest.
- A 'buffer' of less ignition prone lands between suburbs and other land-uses could prove effective. A buffer width of 200 m would significantly alter ignition frequencies. Buffers would also improve fire protection for the interface, and, if properly designed, could reduce maintenance costs - for example, by reducing the need for fire fuel management.

Land Management Agency Liaison

The on-going liaison between Rural Fire Service and Government land management agencies and rural elements of the private sector benefits through use of the model to allow full recognition of the potential impacts of the ignition patterns. The need for plans of management to be prepared or the threat of economic impact drives the timetable for this process.

A number of measures are currently in place in the ACT, including:

- Liaising with land management agencies to ensure that their management goals are linked into ignition patterns. As an example, of two similar sites for a rare plant species, one closer to suburbia will have less chance of long-term survival since it has a higher ignition frequency. Both sites may, however, be given an equal chance of survival by expending more fire suppression or fire protection effort to the area closer to suburbia. However, this requires an on-going commitment and may have a large impact upon a limited budget.
- Where the land management agencies provide fire suppression resources, the deployment of these is optimized with respect to proximity to current ignition patterns, minimizing travel times, and management of the total costs of having resources committed to fire duties.
- We are seeking a better understanding of the reasons when the observed ignition frequency differs greatly from the predicted ignition frequency. Low observed values may be due to some aspect of local land management. For instance, some lands in Canberra are managed as part of the seat of Federal Government and are not used by the public in the same way as other lands. Also, the results of changes in land management may take a number of years to show up clearly in the observations. Finally, localized increases in ignition frequencies may be due to the actions of arsonists, and we are working closely with the Australian Federal Police on utilizing these observations for law enforcement.

These measures may suggest locally applicable ways of preventing fire, but they must also be compatible with any current plans of management. For example, closing an access road into an area of high recreational demand would reduce fire frequency in the area, but this may be counter to public expectations expressed during the preparation of the plan of management.

Standard of response

The predicted ignition frequency pattern can be a cornerstone of cost-effective rural fire protection. The interface transition zone can be used to determine a specific standard for response, based on detection, actual response times and number of units dispatched. Each component of the standard can be optimized with respect to both the standard and cost.

Table 3 highlights some of the problems posed by the transition zone in comparison with other rural lands.

TABLE 3

Comparison of characteristics of the transition zone and other rural lands.

COMPONENT	TRANSITION ZONE	OTHER RURAL LANDS
Ignition frequency	High, rapidly decaying with distance from nearest suburb.	Low, approximately constant, natural ignition patterns prominent.
Detection	Good - '000' calls from public.	Poor. Need commitment to staffing fire tower network.
Access	Good. Many access points from suburbs, frequent vehicular tracks. Some hindrance from drains, etc.	Sparse rural road network, few access tracks. Need to travel cross-country.
Access strategy	Urban units radiate out from urban centres. Rural units deployed at key points on rural periphery, or converge from outer rural areas.	Local units nearby, other units have large distances to travel.

Identification of a separate transition zone permits separate standards of response to be applied:

Transition Zone: As the fire danger index goes up, required response times become shorter, reflecting the expected increase in potential rate-of-spread. Note that in the ACT there is a lower limit of perhaps 10 minutes which cannot be bettered without undue cost to the community.

Other: Response times for first and second units, and their destination with respect to incident, should reflect the value of the Control Urgency Index (**CUI**, McRae 1991), as indicated in Table 4. Control Urgency Index is a component of the ACT Rural Fire Hazard Assessment and reflects proximity to property or resources.

These times could be improved considerably as fire danger index increases and units are strategically deployed, but the degree of improvement that can realistically be achieved represents a balance between the cost of standby and perceived threat to the community.

TABLE 4

Goals for Standards of travel time outside the interface transition zone.

CONTROL URGENCY OBJECTIVE	INDEX	1ST UNIT	2ND UNIT
5	20 minutes	30 minutes	At fire
4	20 minutes	45 minutes	At fire
3	30 minutes	1 hour	At fire
2	45 minutes	2 hours	In area
1	1 hour	As needed	In area

Decision Support for Dispatch

Software has been developed, and is being refined, that uses all of the above elements, and the details of timing and location from the Rural Fire Service standby roster, to advise on the most appropriate units to dispatch to any location. This can be the key to ensuring that the standards of response are met as often as possible.

CONCLUSION

This analysis of historical data for the ACT has confirmed the conventional, subjective opinion that most fires occur close to the urban/rural interface. A clear pattern emerged relating land-use and distance from nearest suburb to the frequency of ignitions.

At a time when the ACT's urban and rural fire services are having to learn how to work together more closely this finding is of great benefit.

The Emergency Management Group has recently redefined the legal definition of the fire services' jurisdictions to reflect land-use planning policies in the Territory's key planning instruments, the Territory Plan, developed by the ACT Government's Territory Planning Authority, and the *National Capital Plan*, developed by the Federal Government's National Capital Planning Authority.

As jurisdiction is now based on land-use, and land-use is being used to quantify fire management on the urban/rural interface, we have been able to resolve what has been a major issue for interface fire protection.

There were insufficient data on ignition patterns to permit proper statistical analysis. Forthcoming fire seasons will see data being collected specifically for this purpose. There is a continuing dilemma in the ACT - the balance between resolution and precision. The area is so small that a compromise must be reached between dividing any data set up to resolve the interaction of determining factors and yet still having enough replicates to allow rigorous analysis. This applies in spatial and temporal analyses. A further problem with temporal analyses is that the growth of the city is so rapid that the extension of the duration of an historical analysis in order to gain extra precision must be cognisant of the fact that past trends may no longer be relevant.

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